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AERIAL SKETCHMAPPING

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INTRODUCTION

Aerial sketchmapping is the most efficient and economical method of detecting and appraising recognizable pest damage over large remote forest areas. Prior to the use of aircraft, forest pest surveys were conducted from vantage points such as ridges and mountain tops.

In 1919 Hewitt (1919) reported the use of aircraft to survey mosquito breeding areas in parts of British Columbia and recommended its use for forest insect detection. In 1920 an open cockpit hydroplane was used to survey an extensive spruce budworm infestation in parts of Quebec and Ontario (Swaine 1921). Since then, airplanes have continued to play an indispensable role in forest pest management. Today forest pest aerial surveys are routinely conducted at least once a year over most of the forests of the United States and Canada.

PURPOSE

The purpose of this manual is to describe the current aerial sketchmapping procedures as practiced by Federal, State, and private organizations engaged in forest pest management. The scope of the manual is comprehensive and covers the subject matter in general terms, rather than dwelling on regional differences in survey methodology or philosophy.

Since forest pests and the damage they cause are dynamic and highly variable, the resulting data will also be highly variable. No two sketchmappers will or can be expected to record the same outbreak in exactly the same way. For this reason sketchmapping should be regarded more as an art than as an exact science. It is important at the outset that this be understood, not only by conscientious sketchmappers who find that their data may not be in close agreement with their peers or with a subsequent statistically reliable aerial photo survey, but also by the forest manager who may want to put the information to use. Sketchmapping is highly subjective, and the resulting data can be no more accurate than the competence of the sketchmapper and the conditions under which the data was obtained.

USES OF SKETCHMAP DATA

Historically the term aerial sketchmapping has been used synonymously with detection. By definition detection means discovery. With this logic, once the damage was discovered, subsequent surveys would probably not be needed. Fortunately, aerial surveys provide the entomologist and forest manager with considerably more information than simply presence, absence or location. Detection, then, is but one step in a series of steps to identify the problem, determine its location, its intensity and extent of damage, and its potential for increase and subsequent damage. This sequence is part of the biological evaluation process and is the basis for recommending alternative causes of action.

DETECTION

Only through prompt discovery of damaging forest pests, can timely effective action be taken to prevent, suppress or salvage damage. Unfortunately, aerial surveys are not always timely since they detect only the damage and not the causal agent. In the case of univoltine bark beetles which attack trees in summer or fall, damage is not visible until the following spring. With multivoltine bark beetles, such as the southern pine beetle, damage is visible within 4 to 6 weeks following attack. Defoliator

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damage, if severe enough, is visible the same season, usually near the end of the larval feeding period. Prompt detection of potentially damaging agents at low population levels can only be accomplished by intensive ground surveys, but these surveys are usually not practical under most forest conditions. Aerial sketchmapping is a practical alternative, particularly in forested areas that are infrequently visited or inaccessible. With carefully planned and coordinated aerial and ground detection systems, no potentially damaging or noticeable outbreak should ever go undetected.

Of the various types of forest damage, insect damage is the easiest to see from the air. Of this group, bark beetle infested trees are the most obvious because they are usually killed outright and their crowns turn from green to various shades of yellow, orange, orange-red and brown. Defoliators, the next most damaging group of insects, do not usually kill the tree outright, but feed on the foliage causing more subtle color changes. Insect defoliation of hardwoods is generally more vivid than conifers, but this depends on the insect and host tree. Some defoliated trees such as ponderosa pine, defoliated by the pine butterfly, exhibit only thin crowns. Repeated defoliation can kill some trees. Damage by sucking insects, such as scales and aphids, can sometimes be seen from the air but usually only when their population level and resultant damage is heavy.

Most damage caused by tree diseases cannot be seen from the air. Some exceptions are heavy brooming and needle blight infections of conifers, some leaf diseases of hardwoods, hardwood declines, openings in the stand caused by root diseases and some mistletoes, thin crowns caused by prolonged dwarf mistletoe infection, and trees killed or weakened by root and stem diseases and subsequently attacked by bark beetles.

Damage caused by agents other than insects and diseases can also be detected by air. Of these, probably the most important is storm damage such as windthrow and snow breakage. Under certain circumstances scattered storm damage provides favorable breeding sites for bark beetles that eventually infest nearby standing trees. In the West avalanche damage can sometimes be important because it concentrates tree damage in protected canyon bottoms where bark beetle populations can erupt and cause localized damage. Heavy windthrow on the edge of clearcuts can also precipitate localized bark beetle outbreaks.

Many other types of damage occur that can be easily mistaken for that caused by insects and diseases. Conifers killed by fire, herbicides, and bear damage, all resemble bark beetle damage. Porcupine feeding resembles damage caused by top killing bark beetles. Trees flooded by high water in canyon bottoms may appear as being defoliated or killed by bark beetles, depending upon the time of observation. Winter drying (red belt), frost damage, and prolific coniferous cone crops may be mistaken for defoliation. Fall coloration of larch, cypress and of many hardwoods may be confused with bark beetle fading.

Many other types of forest activity or events can be detected during the aerial survey. Newly started forest fires, illegal campfires, major road and bridge damage, and earth slumps have all been detected and reported. Forest fires are usually reported through the aircraft's radio to the nearest airport or through an Omni station, or directly to the forest if the aircraft is carrying a local net radio.

EVALUATION

Aerial sketchmap data can aid the biological evaluation process by providing a variety of information.

Locating Areas or Problems to Evaluate. A skilled aerial observer can pinpoint areas to ground crews that should be evaluated on the ground. There may be areas where potential infestations are suspect or where an infestation appears to be building. Potential research areas (Theroux 1976) and other areas exhibiting unusual or extreme conditons can also be located and mapped. Comparative sketchmap records served as a basis for instituting a study to record stand depletion and infestation trends of the mountain pine beetle (Parker 1973; Klein et al. 1977).

Stratification for Damage Surveys. Aerial sketchmap data of bark beetle infestations by damage intensity can serve as a base for multiphase damage surveys (Klein 1979). A stratification map can be produced by grouping the affected trees into separate polygons and converting the tree counts within polygons into intensity classes.

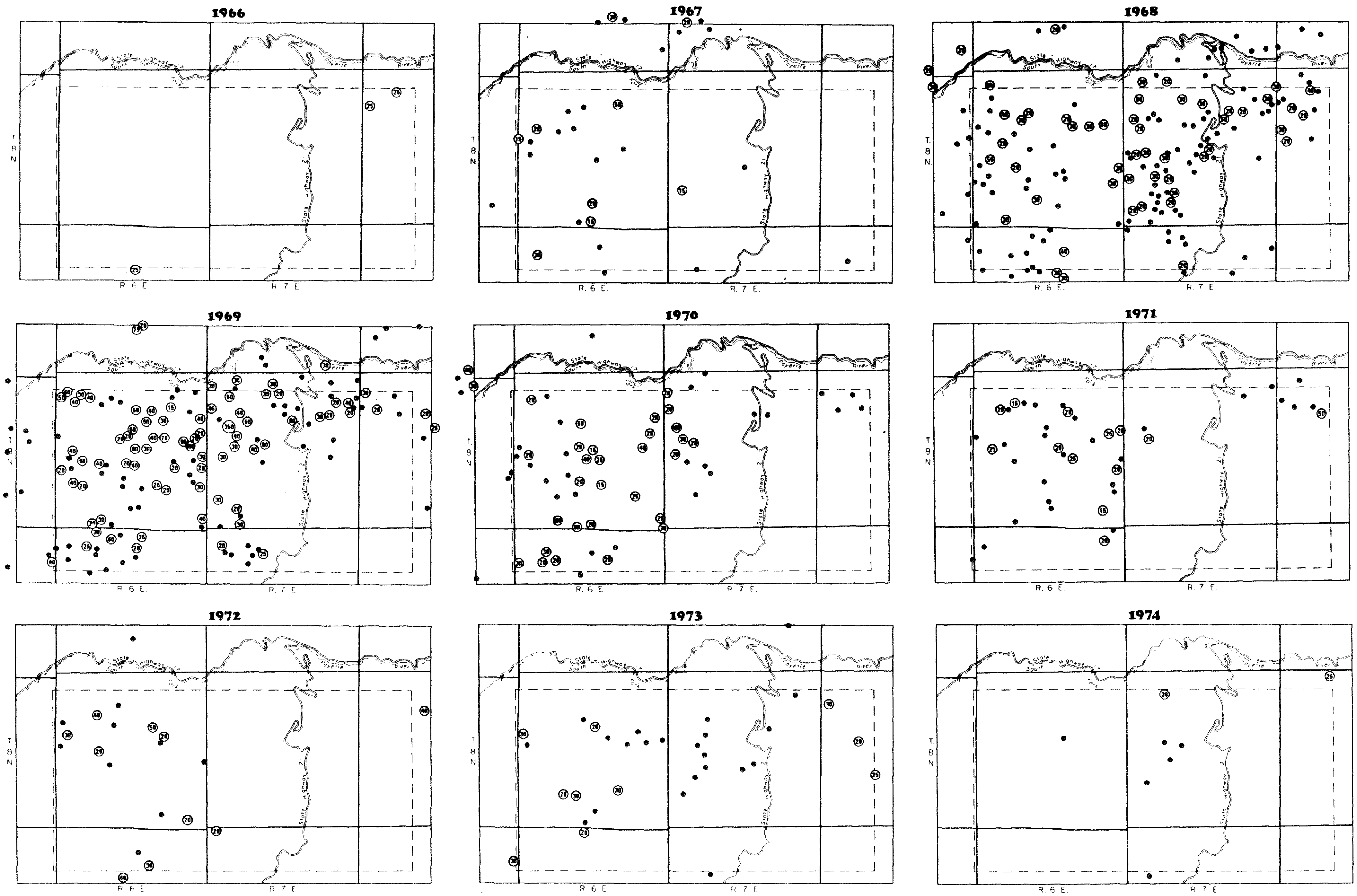
Historical Records. A consistent series of sketchmaps produced over a period of time can provide a historic record of major forest insect outbreaks (Hodson 1977; Shepherd 1977). These sequential records can provide valuable information on population movement, trend, host and habitat preference, and infestation duration. For example, an analysis of consecutive years of sketchmap data in which Douglas-fir was killed by the Douglas-fir beetle in a portion of Boise National Forest, Idaho, showed the outbreak's increase, peak, and decline following extensive snowbreak and windthrow during the winter of 1964/65 (Fig. 1). Using a series of six consecutive years of sketchmap data, Parker (1973) was able to show the apparent progression of mountain pine beetle populations from low elevation lodgepole pine stands into high elevation whitebark pine stands. This data supplemented the evidence against Hopkin's "Host Selection Principle", and provided a basis to advise land managers that whitebark and limber pine stands are not necessarily immune from attack.

Control. Shepherd (1977) analyzed successive years of aerial survey data for several forest defoliators and suggested that a better understanding of outbreak spread and habitat zones would help clarify many of the factors that go into a control decision. The persistence of outbreaks in certain habitat regimes could be a reliable indicator of future hazard. Crookston et al. (1977) constructed a hazard zone map of lodgepole pine stands killed by the mountain pine beetle by accumulating 30 years of aerial sketchmap data, 1945 to 1975.

Sketchmapping has been used almost exclusively to designate boundaries of areas to be aerially sprayed with chemical or biological insecticides. In some cases, the effectiveness of insecticides in protecting foliage has been obtained from aerial sketchmapping.

Salvage. Timely and accurate detection of concentrations of dead and dying timber is imperative to an effective timber salvage program. In the case of some bark beetles, prompt tree removal before beetle flight will not only salvage a resource that would otherwise be lost, but may result in some degree of population reduction. In some bark beetle outbreaks, effective salvage and stand protection can be achieved by removing nearby susceptible green trees as well as the recently infested ones (Amman et al. 1977).

Inventory. Tree counts made from an airplane provide a rough estimate at best and should not be relied on as an inventory technique, except in a general way. Examples would be in comparing the relative numbers of trees affected from one area to another, and in the same area from year to year. The myriad of factors that can have an effect on aerial sketchmapping accuracy are discussed in a subsequent section.



LEGEND

ESTIMATED NUMBER OF DEAD TREES: >10 (20)

ESTIMATED NUMBER OF DEAD TREES: 1-10 •

SURVEY AREA BOUNDARY — — —

Fig. 1 Portions of aerial sketchmaps showing the annual trend of Douglas-fir beetle caused mortality over a nine year period as detected during aerial surveys, Boise National Forest. The infestation in standing live trees was triggered by extensive blowdown during winter of 1964/1965.

METHODS

Aircraft. Experience has shown that high-wing monoplanes make better survey aircraft than low-wing aircraft because they offer better lateral and downward visibility. Four- and six-place aircraft are preferred to two-place aircraft due to their extra capacity, room, and therefore, added comfort (Fig. 2). The number of aerial observers required may range from one to three, depending on the area and type of survey. In addition to personnel, the aircraft must have sufficient room for some of the special equipment carried such as maps, map boards or rollers (Anonymous 1970), cameras, portable radios, personal baggage, and safety and survival equipment.

Aircraft performance is important, especially in mountainous, high altitude flying. In the Southeastern and Northeastern United States, survey altitudes may vary from only 500 to 5,000 feet above sea level in some areas; however, in the far West, common survey altitudes may range from 4,000 to 9,000 feet with some reaching 11,000 feet or higher. During the summer months, where most sketchmap flights occur, these altitudes become even more critical because of "density altitude"[5]. Minimum power requirements for single engine four-place aircraft that fly under 5,000 feet is 150 horsepower; for aircraft above 5,000 feet, 225 horsepower. In parts of the Rocky Mountains and Great Basin where survey altitudes of 7,000 to 11,000 feet are common, turbocharged aircraft will provide an added margin of performance and safety.

It is axiomatic that the faster one goes the less he will see. This applies especially to aerial sketchmapping. Survey aircraft should have slow flight capabilities, at least as slow as 70 mph at sea level. However, at higher elevations, the airspeed should increase to 80 or 90 mph in order to remain airworthy with a good margin of safety. Survey aircraft should also have the capability of taking off and landing on relatively short runways and strips, and have a cruise range of not less than five hours (Tunnock 1978). Aircraft that meet these requirements and have been extensively used for sketchmap surveys are those manufactured by Cessna Aircraft Corporation[6]. The most popular aircraft are the 172, 177RG, (below 5,000 feet), and the 182 (above 5,000 feet). The Cessna 180, 185, 206, and 210 also are used. With the exception of the 177RG and the 210 which have retractable landing gear, all others can be fitted with floats for water takeoffs and landings. Other high-wing, single engine aircraft such as the DeHavilland Beaver also have been used.

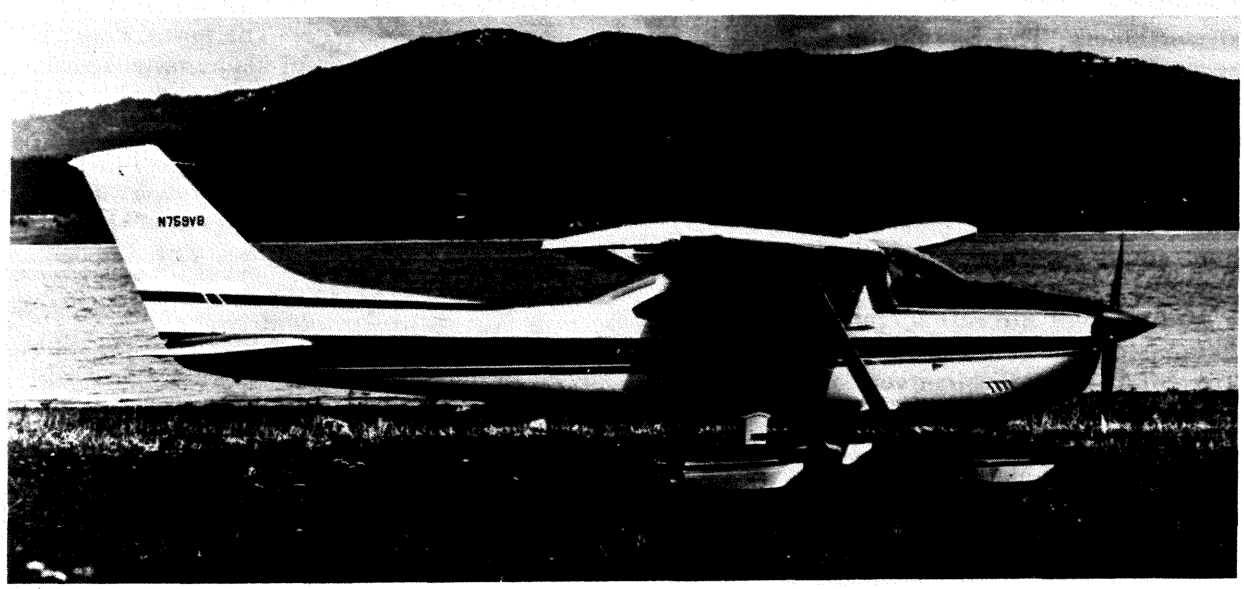


Fig. 2 Cessna Skylane, a four place, high wing monoplane commonly used for aerial sketchmap surveys.

[5]Density altitude is an expression of the air density through which an aircraft flies. It is dependent on temperature, humidity, and altitude. For example, an airstrip may be at an elevation of 3,000 feet but on a given day its density altitude might be computed as 6,000 feet. The aircraft would then perform at 3,000 feet as if it were at 6,000 feet.

[6]Mention of commercial products is for convenience only and does not imply endorsement by USDA Forest Service.

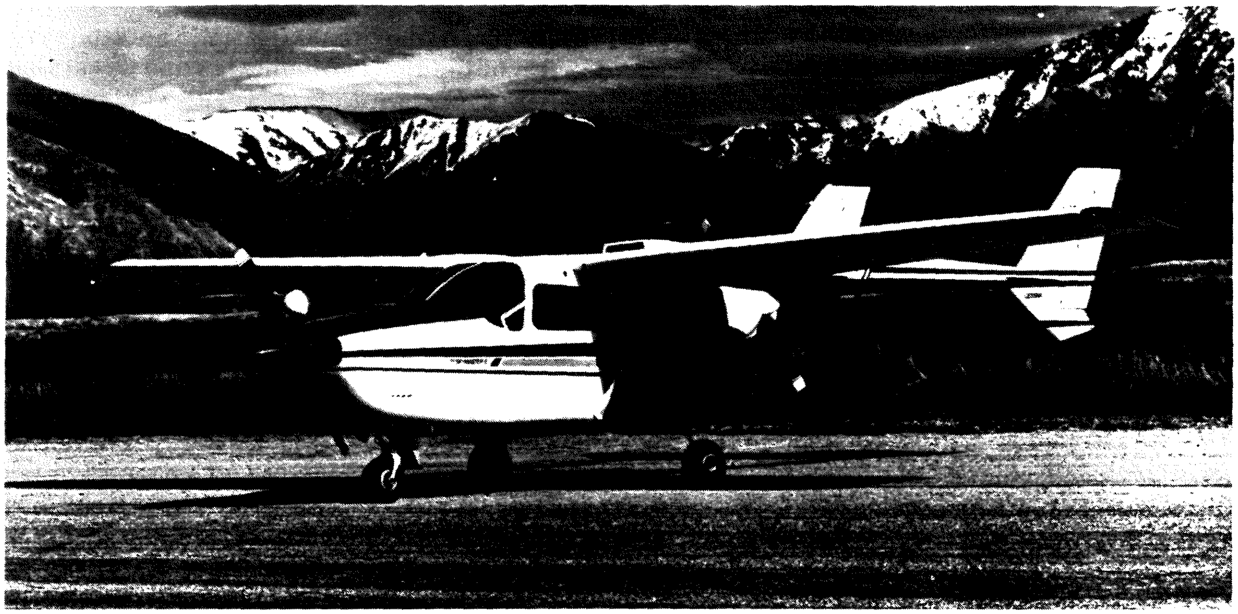


Fig. 3 Cessna Skymaster, a six place, highwing, twin engine monoplane used for aerial sketchmap surveys. This aircraft can be converted to short takeoff and landing (STOL) operation.

In some of the more mountainous areas the trend is toward two-engine aircraft. The center line thrust Cessna Skymaster (337) (Fig. 3) and the Aero Commander (500) are such aircraft. Two engines decrease the probability of complete engine failure but the aircraft are heavier and must be flown at higher speeds to maintain airworthiness. The Skymaster because of its protruding engine cowl has only fair forward visibility but excellent lateral and downwind visibility. The Aero Commander has excellent all-around visibility from the front seat but poor visibility from the back seats because of the small windows. The "pressurized" Skymaster has small windows which also restricts visibility.

Many small aircraft including the Cessna Skymaster can be modified to a STOL (Short Takeoff And Landing) conversion which permit slower than normal flying speeds and short airstrip operation. The STOL type of conversion, although desirable, adds to the cost of the aircraft and consequently to the cost of the operation.

When flying at relatively high altitudes, 7,000 feet and over, turbocharged engines will increase the aircraft's performance and provide an extra margin of safety. At lower elevations, generally below 7,000 feet, turbocharged engines offer no advantage.

Helicopters make an excellent surveillance aircraft but their operating costs are considerably higher than fixed-wing aircraft. Helicopters are ideally suited for intense surveys of small areas such as mapping concentrated windthrow and salvage opportunities. Since their cruising speed is considerably less than fixed-wing aircraft, ferry distances should be kept to a minimum.

The Aerial Observer. The aerial observer is the key to a successful sketchmap operation. Experience has shown that the attributes of an aerial observer should include:

1. A working knowledge of forest insects and disease indigenous to his area of responsibility, their life cycles, and the type of damage they do.

2. An ability to identify major tree species indigenous to his area of responsibility.

3. A desire to fly and not be subject to vertigo or motion sickness.

4. Good eyesight and normal color perception.

5. An ability to read maps and to orient between air and ground.

6. At least 100 hours in the air as a trainee and two seasons on the ground participating in routine detection and evaluation surveys.

The number of observers required for a sketchmap mission may vary with the type of aircraft, terrain, pattern of flight, and type of information needed. Most survey aircraft are four-place and can accommodate a pilot and three sketchmappers. This arrangement is suited to the grid pattern of flying over relatively flat terrain. The observer in the right front seat acts as navigator while the observers in the rear detect and map those infestations visible on their respective side of the aircraft. Generally, each observer views a strip which can vary from 1/2-mile (Aldrich et al. 1958) to 2 miles (Wear and Buckhorn 1955) in width. The width of the strip may vary with elevation above terrain, the interval between strips, and intensity of survey desired. Under other circumstances, only two observers may be needed, one in the right front seat, and the other in the left rear seat. Both observers map from their respective sides of the aircraft but the front observer also navigates.

In steep mountainous terrain only one observer is commonly used. This is done primarily as a safety measure to save weight, thereby increasing climbing power should an emergency situation arise. The single observer is often highly skilled. A second observer is included for training purposes only (Tunnock 1978).

Planning A Mission

The success of a sketchmap mission will depend largely on a clear definition of objectives and on the quality of planning. Mission objectives should be spelled out and planning should begin well in advance of flights. Previous years' sketchmaps should be reviewed and priority areas designated. Inquiries should be made to field units as to problems, and the field units should be notified beforehand of intended flights.

Equipment. Equipment vital to the survey should be assembled in kit form and taken on every flight. This equipment should include:

1. Maps of desired scale
2. Colored pencils or pens
3. Map boards or map roller
4. Sunglasses
5. Small format camera
6. Small tape recorder
7. Safety equipment and clothing (see Safety section).

In the event inclement weather precludes a flight in a planned area and an alternative area has to be selected, it is important that the kit contain a *complete* set of maps of all the forested areas to be flown. Having the correct map on hand would eliminate the inconvenience, expense, lost time, and frustration in having to procure one in the field or having to return to the home base.

Airfields. The location of landing fields or airstrips planned for each day's flight should be known. Information as to their surface (paved, gravel or dirt), length, elevation, gasoline and octane availability, and orientation should be known and recorded. Many states produce aeronautical charts or maps which give this information. If an overnight trip is intended, ground transportation to and from the motel should also be planned.

Filing a Flight Plan. If possible, a flight plan should be filed before each flight. This would be the time to inquire as to weather conditions in or near the survey area. In backcountry airstrips where radio contact is poor or nonexistent, a flight plan can sometimes be filed once airborne. Also, once airborne, it is advisable to give periodic position reports (see Safety Section).

Alternate Areas. Inclement weather is one of the most frequent and important variables encountered during a survey, especially in mountainous terrain. Prior to taking off, one or possibly two alternate areas should be preselected in the event poor weather conditions are encountered in the primary survey area. There will be instances where weather conditions are bad everywhere, resulting in a "sitting out" period at the nearest available airport.

Maps. The appropriate maps should be chosen and indexed before each flight. In selecting maps an important initial consideration is scale. A large-scale map will permit more accurate positioning but will be flown over more quickly; conversely, a small-scale map will be less accurate but will take longer to fly over. With large-scale maps, more maps will be required to cover a particular area than with small-scale maps. For example, four 7½ minute (1:24,000) quadrangles cover the same area as one 15 minute (1:62,500) quadrangle. Flying from map to map is extremely difficult, especially in the cramped confines of an airplane cockpit. In some situations where long

straight flight lines are flown, portions of maps can be pasted together and placed in a specially designed map roller (Anonymous 1970).

Large-scale maps and other maps can be effectively used for special surveys in very small areas. USGS topographic quadrangle maps of the 7½ and 15 minute series and Army Map Service maps (1:250,000) show forested and non-forested areas, and their contour lines can aid navigation. Ortho photo maps are ideally suited for pinpoint surveys, but their large-scale (1:24,000) and their present unavailability in most areas make their use limited. Reduced scale photo mosaics of large-scale photography are also available in many areas. In the western National Forests the most commonly used maps for aerial sketchmapping are the Forest Service planimetric maps of 1:126,720 scale (1" = 2 miles). They are accurate, show moderate detail, and are periodically updated and improved; and are essentially a compromise of scale and size. In most other areas, where forest or topographic maps are not available, county maps may be used. Generally, however, they lack topographic detail but show political boundaries and roads[7].

LANDSAT images, printed and enlarged to a desired scale, can also be used (Myhre 1980) for aerial navigation although they may lack some necessary detail. Some advantages of LANDSAT imagery is that it would show most large forested areas and some recent land form changes.

Patterns of Flight. A particular flight pattern will depend primarily on the type of topography to be flown, the area to be covered, and the level of accuracy desired. There are basically two types of patterns, contour and grid (Fig. 4).

Contour Pattern. This pattern is flown in areas of relatively steep, well defined topography, or in situations where rather detailed information is desired. Contour flying means that the aircraft is flown in a left-hand pattern generally parallel to the drainage patterns rather than across them. The principal observer, sitting in the right front seat of the aircraft, keeps the drainage always to his right. In steep, wide canyons, the canyon is entered somewhere between the ridge on the left of the aircraft and the drainage on the right. The sketchmapper then surveys that portion of the canyon to his front and the canyon bottom and opposite slope to his right. Once the upper reaches of the canyon are reached, the aircraft makes a 180° turn to the right, crossing the head of the drainage, and continues down canyon between the ridge and canyon bottom, permitting the observer a limited forward view but a complete view of the opposite slope. The sketchmapper can also observe laterally to his left, either in front or back of the pilot. Once out of the canyon, the observer may elect to make a 360° turn to the right before entering the next canyon, or a 180° left turn. The 360° technique allows better visibility of the canyon mouth and also allows the pilot to "set up" the aircraft and perhaps gain more altitude before entering the next drainage.

Grid Pattern. The grid pattern is generally flown in flat, poorly defined terrain such as that in the southeast or in mountainous terrain where only cursory information is desired. In maintaining a grid pattern the aircraft is flown in a straight line back and forth along parallel flight lines. The distance between flight lines may vary from 1 to 6 miles, the lesser distances resulting in a more accurate survey. Usually the flight lines are predetermined and drawn on the map prior to the flight. The starting and ending points of each flight line should be well defined.

Visual orientation along long straight flight lines can be difficult, especially over flat and poorly defined terrain. This long standing problem has been minimized by installation of electronic navigation systems in the survey aircraft. One such system, LORAN-C, is now being used by personnel of the Southeastern Area, State and Private Forestry and the Texas Forest Service (Dull 1980). The system is portable and can be installed in different aircraft.

Regardless of the pattern flown, the exact location of the aircraft in respect to the ground should always be known. This can be done by tracing the actual path of the aircraft on the survey map.

[7]A brochure entitled "Types of Maps Published by Government Agencies" can be obtained from: U.S. Department of Interior, Geological Survey (NCIC), 507 National Center, Reston, Virginia.

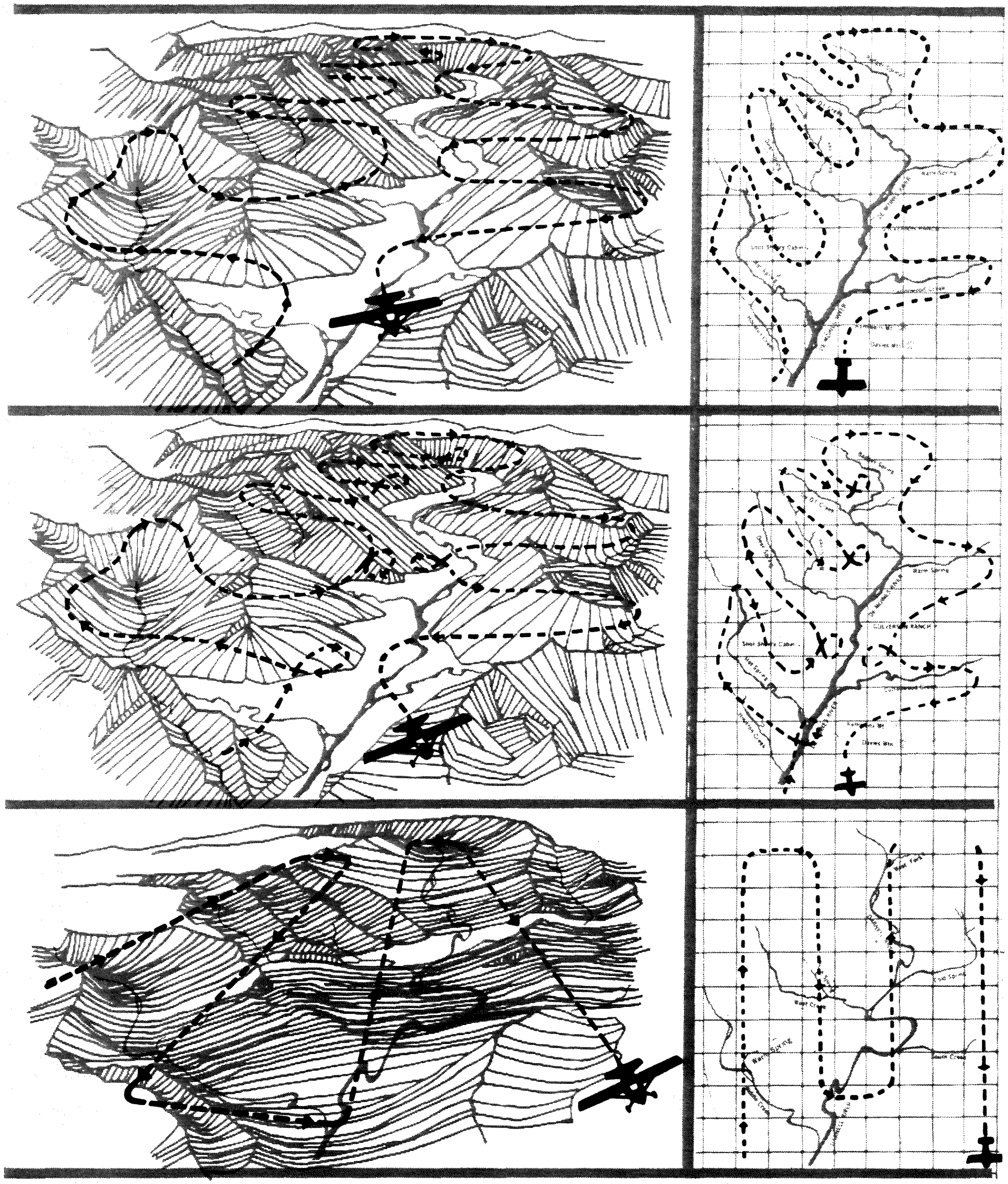


Fig. 4 Illustrations showing three aerial sketchmap flying patterns: A, contour flying with 180° left turns; B, contour flying with 360° right turns; and C, grid flying along predetermined, usually parallel flight lines.

Survey Timing. Most aerial sketchmap missions are flown when insect activity and resultant damage is at a peak. Ideally, a survey could be scheduled for individual pests, but because of the myriad of pests and the extensive areas requiring coverage, this is not practical. Fortunately, many forest pest life cycles overlap and can be surveyed simultaneously (Table 1). In the West, most bark beetle damage and conifer defoliation begins to appear by late June and early July; consequently, aerial surveys begin then or shortly after and continue through September or mid-October. In the South where bark beetles have several generations, aerial surveys have to be closely coordinated with the insects life cycle in order to

Region Insect(s)	Host(s)	April	May	June	Observation Period July	Aug.	Sept.	Oct.	Nov.
WEST									
Mountain pine beetle	Pines								
Western pine beetle[2]	Ponderosa pine								
Ips beetles[3]	Pines								
Douglas-fir beetle[3]	Douglas-fir								
Spruce beetle	Spruce								
Western budworm	True firs, Douglas-fir, spruce, larch								
Douglas-fir tussock moth	Douglas-fir, true firs								
Hemlock Looper	Hemlock, Douglas-fir, true firs, spruce								
Lodgepole pine needle miner	Lodgepole pine								
Larch casebearer	Western larch								
NORTHEAST, LAKE AND CENTRAL STATES									
Spruce budworm	Balsam fir, spruce								
Gypsy moth	Hardwoods								
Forest tent caterpillar	Hardwoods								
Fall cankerworm	Hardwoods								
Elm spanworm	Elm, oak, maple, hickory, ash								
SOUTHEAST									
Southern pine beetle[5]	Southern pines								
Ips beetles[5]	Southern pines								
Forest tent caterpillar	Hardwoods; esp., water tulepo								
Balsam wooly aphids	Fraser fir, balsam fir								
Poplar tentmaker	Cotton wood								
Fall cankerworm	Hardwoods								
Elm spanworm	Hardwoods								
Oak leaf tier	Hardwoods								

[1]These periods will vary with latitude, elevation and climatic conditions.
[2]In the southern part of its range, the western pine beetle may have up to four generations annually.
[3]In the southern part of their range, Ips *spp.* may have up to five generations annually.
[4]Some Douglas-fir fade the season of attack while others fade the following spring, requiring two flights.
[5]The southern pine beetle and Ips beetles can have up to seven generations annually.

Table 1 Generalized detection periods for damage caused by several major forest insects in the United States.

distinguish between successive generations and estimate trends. In hardwood forests flights made too early in the spring before defoliation peaks or during late summer after the trees refoliate may underestimate both the intensity and extent of defoliation. In the Northern Rockies defoliation by larch looper is not readily visible until mid-September. Problems such as these may require special flights.

During the summer the sun is at its peak which means long days and minimum shadow effects. Generally, a flight begins around 8:00 a.m. and ends before 2:00 p.m. If the morning flight is on predominately east facing slopes, the flight may begin earlier; conversely, if on west facing slopes, it should start later.

An average reconnaissance flight, including ferry time to and from the survey area, may last four to five hours. Under ideal flying conditions flights may last six hours, but this is extreme and should be avoided due to pilot and observer fatigue. Although no data is available, it is suspected that observer efficiency reaches a peak somewhere near the second or possibly the third hour of flight and then diminishes rapidly. At least one, one-half to one hour rest break should be taken during each day's flight.

Sketchmapping. When an outbreak is detected it is identified as to causal agent and host, and its location is marked on the survey map. Large outbreaks are drawn as polygons while very small infestations, usually less than 10 trees in a group, are designated as a dot (Fig. 5). If many small groups are widely scattered over a large area, they may be included within the boundaries of a single polygon. An abbreviated code representing the causal agent and host is usually placed alongside the infestation spot or within its boundaries (Table 2). Damage intensity is usually estimated in two ways, by numbers of trees (bark beetles) and by defoliation intensity (defoliators). Defoliation is usually estimated as to percent defoliation and classed as light (L), medium (M) or heavy (H). These estimates —

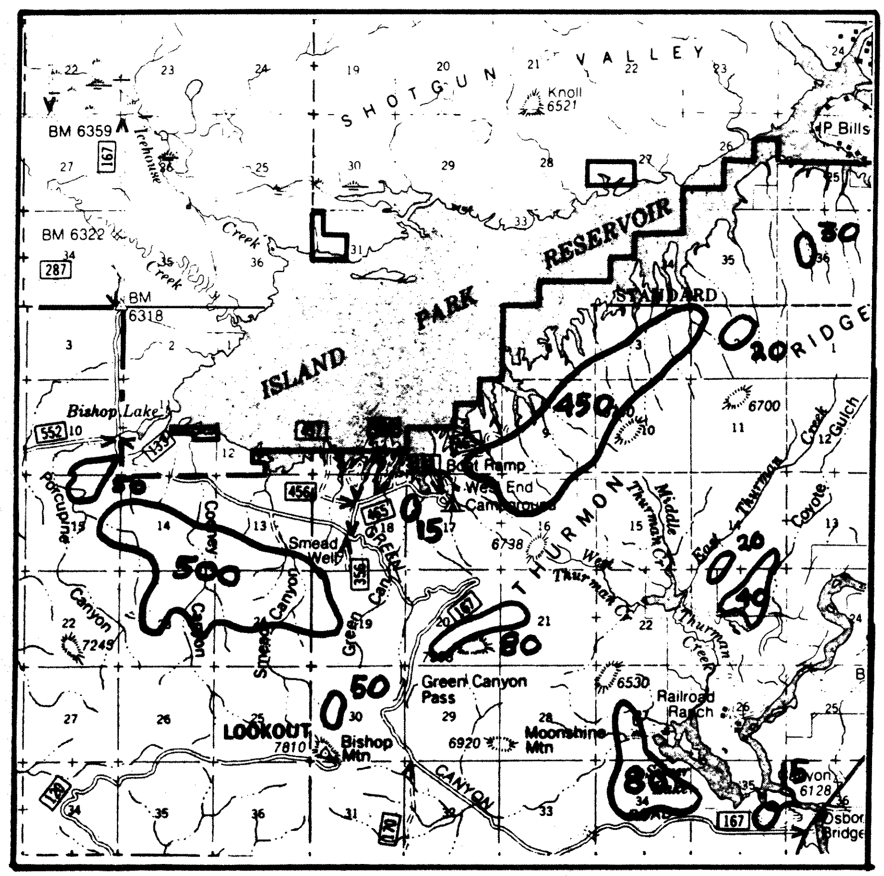


Fig. 5 Map segment showing location of concentrations of tree mortality resulting from an aerial sketchmap survey. Numbers inside the polygons are estimates of numbers of dying lodgepole pines.

	BARK BEETLES	HOST
1	— Douglas-fir beetle	Douglas-fir
2	— Douglas-fir engraver	Douglas-fir
3	— Engelmann spruce beetle	Engelmann spruce
4	— Fir engraver	True firs
5	— Hemlock engraver	Western hemlock
6L	— Mountain pine beetle	Lodgepole pine
6P	— Mountain pine beetle	Ponderosa pine
6W	— Mountain pine beetle	Western white pine
7	— Oregon pine ips (coded L, M or H)	Ponderosa pine
8	— Western pine beetlePonderosa pine	Ponderosa pine
9	— Silver fir beetle	True firs
	DEFOLIATORS (coded L, M or H)	
BB	— Budworm, black-headed	True firs — hemlock
BL	— Budworm, larch	Western larch
BP	— Budworm, pine	Ponderosa & lodgepole pine
BS	— Budworm, spruce	Douglas-fir, true firs, & spruce
CL	— Casebearer, larch	Western larch
HL	— Hemlock looper	Western hemlock
NL	— Needle miner, lodgepole	Lodgepole pine
NP	— Needle minor, ponderosa pine	Ponderosa pine
OL	— Oak looper	Oregon white oak
PB	— Pine butterfly	Ponderosa pine
PM	— Pandora moth	Ponderosa pine
SF	— Sawfly, fir	True firs
SH	— Sawfly, hemlock	Western hemlock
SL	— Sawfly, lodgepole	Lodgepole pine
SP	— Sawfly, ponderosa pine	Ponderosa pine
TM	— Tussock moth, Douglas-fir	Douglas-fir, true firs
Z	— Zeiraphera Sp.	Douglas-fir, true firs
	SUCKING INSECTS	
AB	— Aphid, balsam woolly	True firs
AS	— Aphid, spruce	Sitka spruce
M	— Mite, spider	Douglas-fir and true firs
PS	— Pine scale	Ponderosa pine
	MISCELLANEOUS	
B	— Bear damage	Predominately Douglas-fir
H	— Dying hemlock	Western hemlock

Table 2 Example of a sketchmap coding scheme using combinations of numbers and letters to designate causal agent and host. This code is used in the Pacific Northwest (Buckhorn and Wear 1955).

numbers of trees for defoliation category — are written alongside the causal agent symbol. In some areas different colors are used to designate the causal agent, host, and defoliation intensity rather than symbols. Damage of unknown cause should be marked with a question mark for subsequent examination on the ground.

Aerial Photography. A small format camera should be considered as standard survey equipment. Of the many small cameras available, the 35 mm single lens reflex camera appears to offer the best compromise of cost, weight, film size, versatility, and overall utility (Fraga 1978). A 35 mm camera produces good quality imagery from medium to low elevations and can be used effectively by anyone with average photographic ability. Better photographs will result by shooting through an open window. A full range of accessories, such as interchangeable lens, filters, and motor drives are available with most 35 mm single lens reflex cameras. A wide assortment of films are also available, including color infrared.

A small, slow flying aircraft, is an ideal camera platform for producing oblique or vertical color photographs or slides of various types of forest damage. The pictures can be used for training, documenting year-to-year damage trends in specific areas, aiding ground crews in locating hard-to-get-to areas, enhancing biological evaluation reports, and providing the land manager with tangible evidence of damage.

SKETCHMAP ACCURACY

A number of environmental and physical factors affect the sketchmapper's judgement and influence his ability to accurately detect, locate, and estimate the amount of forest.

Ground Speed. Ground speed is the actual speed that an aircraft flies over the ground. The faster the speed, the less time the sketchmapper will have to react. For example, an aircraft flying at 100 mph covers one-half mile in just 18 seconds, the time it may take an observer to fold a map.

Elevation. The farther away an object is the more difficult it is to see. However, the greater the elevation the easier it is to orient, particularly over poorly defined terrain, although individual trees become correspondingly smaller. Light or incipient infestations can easily be overlooked. Most surveys are flown between 500 and 1,200 feet above the terrain. In some of the larger canyons in the West two passes at varying elevations are usually made.

Fall Coloration. Flights made in fall when fall coloration occurs should be avoided since this phenomena can easily be mistaken for tree damage.

Turbulence. Weather can greatly affect survey efficiency and accuracy. Turbulent conditions cause physical discomfort and often result in disorientation. The main causes of turbulence are: (1) vertical air currents, (2) wind shear, and (3) air moving over and around mountains (Imeson 1975). Turbulence is generally more severe on the lee side of ridges (downdrafts) than on their windward side (updrafts). Turbulence will also increase with increasing air temperatures. Flying through clouds and during thunderstorms should be avoided.

Light. Surveys should be flown under optimum light conditions, but this is not always possible. Flying early or late during the day or season results in long shadows and generally poor visibility (see Survey Timing). Shade from scattered, dense cumulus clouds creates a stark contrast with the illuminated area and can impair visibility. A high cirrus overcast may permit detection of bark beetles and other obvious forms of damage, but makes detection of more subtle damage such as defoliation considerably more difficult. Summer haze, frequently encountered in the East and South, greatly reduces visibility and accuracy.

Safety. All aircraft considered airworthy have to meet FAA specifications for performance and safety. Many Federal and State agencies supplement these specifications with their own requirements. These requirements, which also may include pilot qualifications, should be precisely spelled out in the contract, rental agreements, or other documents used to negotiate aircraft use. The contract may also require the aircraft to be inspected and the pilot given a check ride by a qualified examiner prior to acceptance. Many organizations have health and safety codes which should be adhered to. Some important safety considerations are:

1. A flight plan should be filed whenever possible. In some back country landing strips this may not be possible, but once airborne, a flight plan can be filed by radio. Deviations from the intended plan should also be filed, and the plan promptly closed at flight's end. Failure to close a flight plan may result in an unnecessary search.

2. Many Forest Service and State survey aircraft establish additional radio communication by use of local net portable radios. The aerial observer establishes a reporting schedule with the ground station, and gives position reports at specified time intervals (Tunnock 1978). If radio communication is not possible, a telephone check-in system should be established with the observer's supervisor or duty station. The call should be made after each flight and recorded on a daily log. Information logged should include the aircraft type, its color and FAA number, and the area planned for survey the following day. If an airport change is planned, the new airport and expected time of arrival should be logged. This should *never* be left for chance!

3. A radio locator beacon, fire extinguisher, first aid kit, flashlight, and FAA approved shoulder harnesses should be standard equipment for each survey aircraft.

4. If aerial surveys are undertaken in relatively inaccessible areas, personal survival equipment should be taken and stowed in the baggage compartment. This might include a warm (down) jacket, a stocking hat, hiking boots, a pocket knife, waterproof matches, and at least two days supply of lightweight (dehydrated or freeze dried) food.

5. Some organizations require that personnel flying in helicopters and fixed-wing aircraft wear fire retardant (NOMEX) clothing. This includes one-piece coveralls and gloves. The coveralls should fit rather loose and be large enough to fit over regular clothing. A crash helmet will give additional protection. This protective gear is worn extensively by the military and has proven effective in preventing or reducing the severity of burns.

6. The number of personnel in an aircraft should be kept to a minimum. Extra bodies add weight and reduce the aircraft's performance, especially at higher elevations.

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